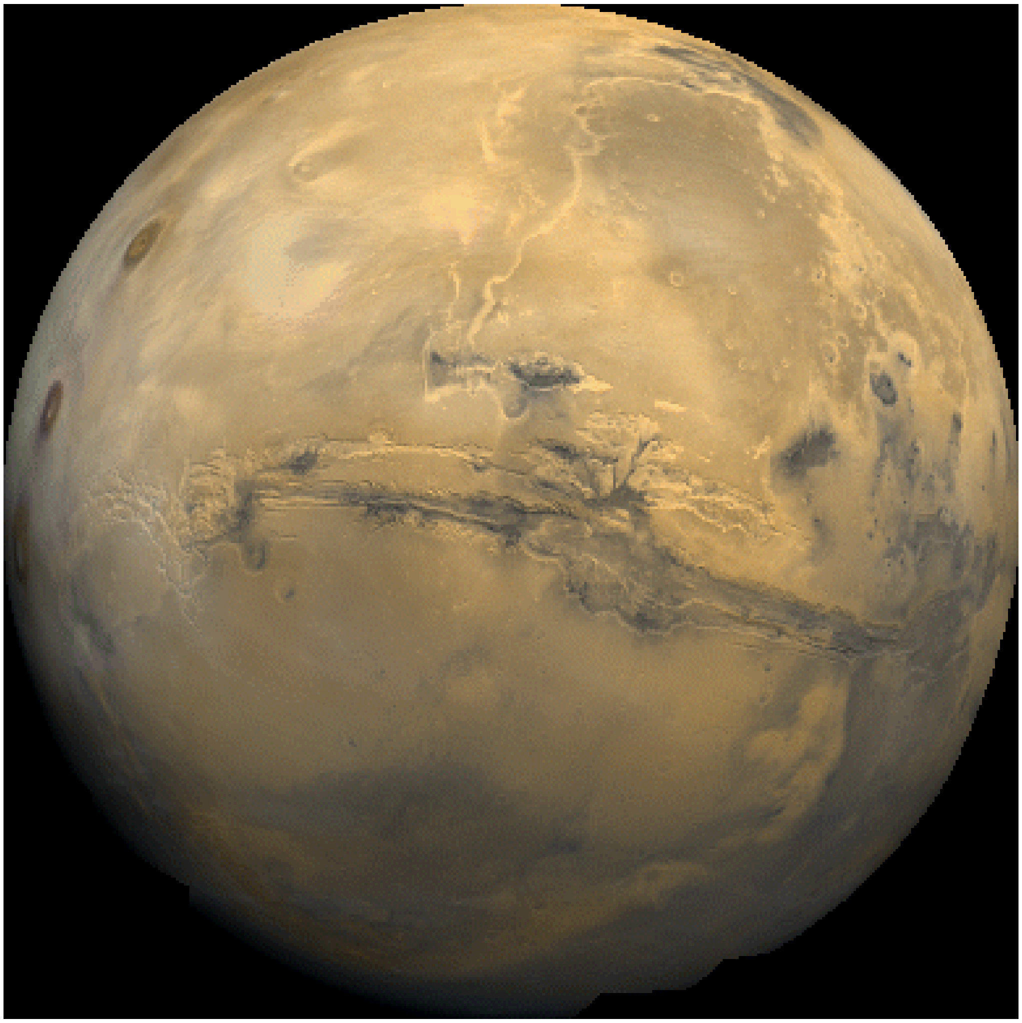
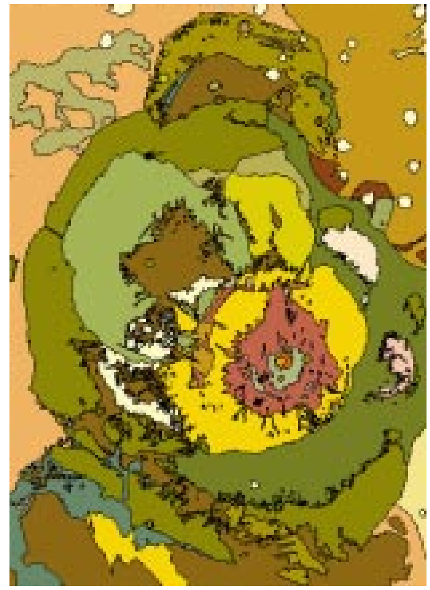
MARS



Lesson 3 - Making Geologic Maps of the Planet Mars

Making Geologic Maps of the Planet Mars



Tharsis Volcanic region, Mars.
From USGS

Objectives:

- Construct a terrain model from a geologic map
- Interpret the geologic history of a region of Mars by making a geologic map using a Viking photomosaic as a guide
- Create a model and then create a geologic map of a cross-section of the model
- Apply fundamental geologic principles in creating geologic terrain models and a geologic map

AZ Standards:

- **6SC-P4.** Use evidence (e.g. fossils, rock layers, ice cores, radiometric dating) to investigate how Earth has changed or remained constant over short and long periods of time. **PO 1.** Provide evidence for changes in Earth's geologic history using data from relative age-dating techniques.
- **1SC-P2.** Compare observations of the real world to observations of a constructed model. **PO 1.** Assess the capability of a model to represent a "real world" scenario.

Time Needed: 1 or 2 class periods for each lesson

Grade Levels: 7th – 12th

Background:

A **geologic map** is a 2-dimensional representation of a 3-dimensional landscape. Overlain on the topography are shown the distribution of **rock units** and types, structural features, such as faults, folds, impact craters, and other geologic information. The main purpose of a geologic map is to aid geologists in interpreting the geologic history of a region. This includes determining what processes helped form and modify the terrain. Some of these processes are **erosion, deposition**, **tectonics**, **volcanism**, and **impact cratering** (see Planetary Processes section of the Astrogeology Resource Packet).

The first thing geologists do when making a geologic map is distinguish different map units according to rock type, composition, and age. The age relationship between units must be determined using the **Principle of Superposition**, the **Law of Cross-cutting Relationships**, and the **Principle of Embayment**. The Principle of Superposition states that layered rock units are laid down one on top of the other, with the oldest rocks on the bottom and the youngest rocks on top. The Law of Cross-cutting Relationships states that for a rock unit to be modified by erosion, faulting, or impact craters, it must first exist as a unit. Therefore, if a rock unit is disturbed by an impact crater, then the rock unit must be older than the impact crater, (i.e. it was there first). Embayment means that a unit flooding (embaying) into another unit must be younger. On planets such as Mars the volume of impact craters on a specific surface can also be used to determine relative ages of units (see Impact Craters Module, Lesson 6).

A **map key** and **stratigraphic column** accompany all geologic maps. They are always located alongside the map. These guides help readers understand the symbols and geologic units used within the map area. Geologic maps on Earth are generally created by geologists who go out and field check the map area. Since it is difficult to field check other planets, planetary geologists must create geologic maps from images sent back by orbiting spacecraft. This 3-part lesson will allow students to construct their own geologic maps. **Part A: Geologic Mapping of Erosional Landscapes,** will allow students to construct a model of eroded horizontal sedimentary rock units using the principle of superposition. Many features on Mars such as the Vallis Marineris are analogous to canyons on Earth like the Grand Canyon. **Part B: Geologic Mapping of Depositional Landscapes,** has students construct a terrain model from a geologic map of depositional rock units such as lava flows, alluvial fans and mass wasting deposits. Many such depositional environments are found on Mars such as in the Tharsis region and the Vallis Marineris. **Part C: Geologic Mapping of Deformed Landscapes,** will allow students to create a terrain model of deformed or folded rock units.

Vocabulary:
Geologic map, rock unit, erosion, deposition, tectonics, volcanism, impact cratering, Principle of Superposition, Law of Cross-cutting Relationships, Principle of Embayment, map key, stratigraphic column

Part A: Geologic Mapping of Erosional Landscapes
Students will create a model terrain of eroded horizontal sedimentary rock units using a geologic map as a reference.

Background/Introduction:
Many horizontal layers are revealed in Vallis Marineris and in impact crater walls on Mars. Show *Overhead A1* of Mars and point out Vallis Marineris, the long scar across the center of the planet. Vallis Marineris is a canyon nearly 2500 miles long, 400 miles wide in places, and up to 4 miles deep. Compare its size to the Earth's Grand Canyon, (*Overhead A2*) which is 277 miles long, about 18 miles wide in several places, and 1 mile deep. The Grand Canyon would easily fit into a small side canyon of Vallis Marineris. Rock layering similar to that seen in Grand Canyon appears on Mars in the walls of Vallis Marineris and within impact craters *(Overhead A3)*. Erosional and tectonic processes often expose rock layers on Earth. A diagram of how erosion may work to expose layers on Mars is shown in *Overhead A4*.

Materials:
- Enough clay or play dough (5 different colors) for each group. Recipe included at the end of this lesson.
- Plastic knifes or Popsicle sticks (provided)
- Shoeboxes or plastic boxes, clear boxes allow students to see side view (provided)
- Erosional landscape geologic maps and color keys (provided)

Procedure:

1. Divide students into groups of 4.
2. Each group will receive a labeled (A, B, C, D, etc…) box, 5 bags of assorted colored clay or play dough (labeled 1-5), color key, and a plastic knife.
3. Groups will lay down 5 rock layers (units) out of the clay or play dough and place them on top of each other in the box in order from 1 to 5 with number 1 on the bottom, representing the oldest rock unit. This procedure follows the Principle of Superposition. Check that each group's initial model resembles Figure 1. Map colors may be different than clay colors.
4. After all the layers are placed in the box, each group will receive an erosional landscape geologic map. Using the map as a guide, they will construct a terrain model that mimics the geology shown on the map.
5. Students will use the plastic knife to outline geologic contacts (the lines that separate rock types). They will then cut away the unneeded rock layers to expose layers corresponding to the map. Each member of the group will have a chance to cut away at least one eroded layer.
6. Students should use the key included with the geologic map to make sure layers are in the correct vertical sequence.

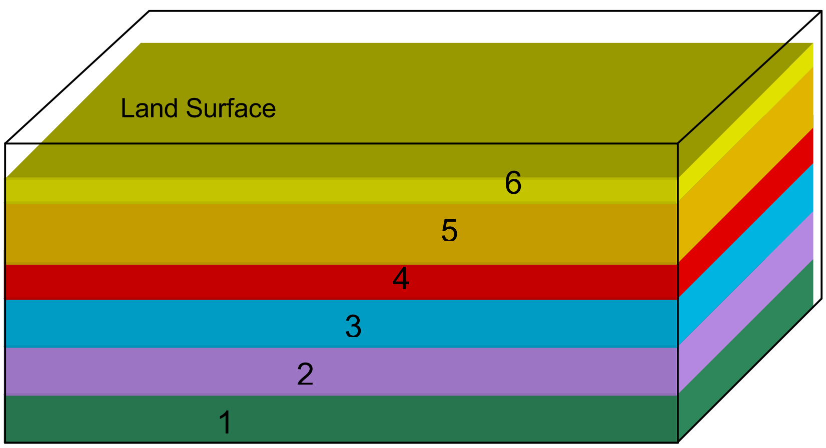


Figure 1. Starting view of Box from side and front.

7. The finished terrain model could resemble the one below.

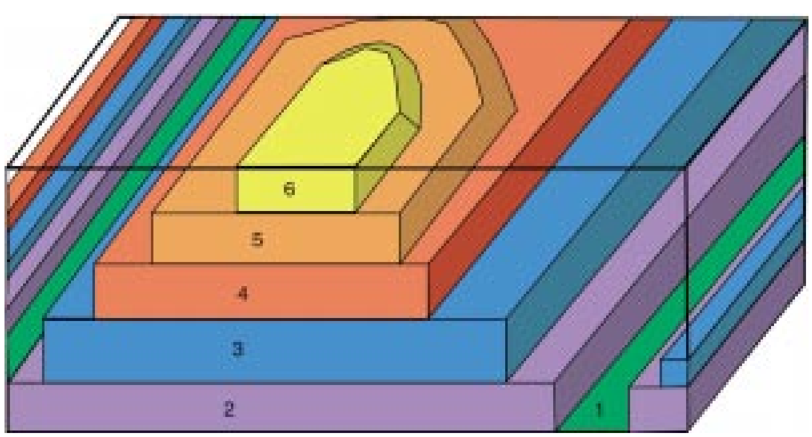


Figure 2. View of the Box after model is completed.

Assessment:
After groups have completed their models, have them answer the questions on the student sheet and then take their models to the front of the room. Collect the student question sheets and corresponding geologic maps. After all students have completed this, set up the models and the maps on a table in random order. Have the students match the correct model to each geologic map and collect their answers.

Play dough Recipe:
1 cup flour
½ cup salt
1 Tablespoon oil
2 teaspoons cream of tarter
1 cup water
Food coloring

Mix all ingredients in saucepan. Heat on low, stirring constantly until dough is evenly mixed and forms a ball. Knead slightly. Store in an airtight container or plastic baggie.

Part A: Geologic Mapping of Erosional Landscapes - Student Sheet

Name________________________________

Directions:
Each group will create a 3-D model of the geologic map given to them. Use different colors of clay or play dough to represent the different rock units on your map. There are a few simple rules that must be followed in order to receive credit for your model.

- Each bag of clay has a number on it. This number represents the order in which the clay (rock unit) will be laid down in your box (see color key). They are numbered 1 to 5 (oldest to youngest). Bag 1 is the oldest unit and should be the first rock unit you put in the box. Rock unit 5 should be the last layer put in the box.
- The colors on your maps are also labeled 1-5. Each label matches a color of clay. All units should be matched with the same color clay as on the geologic map.
- Each unit can ONLY be laid down one time.
- The layers do not have to be the same thickness but each individual layer should have a uniform thickness.
- When creating your model, each new layer can *only* be placed on the layer directly below it. For example, layer 2 can only be placed on top of layer 1 and layer 5 can *only* be placed on top of layer 4. Layer 5 can't be placed directly on top of layer 3.
- If an older layer is exposed on the map, this implies younger units have been eroded off it.

Questions:

1. How can you tell which layer is oldest? Youngest? What principle supports your answer?

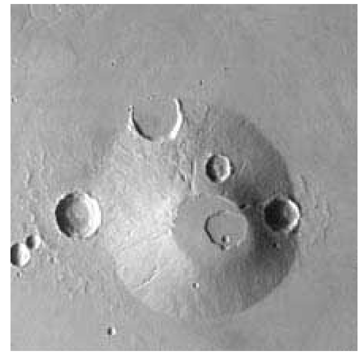
2. How did you get bottom (older) layers to show in your model?

3. Does your model look similar to your map?

4. Create an erosional history of your map area. Describe which areas of your map have eroded away and what geologic processes could have caused the rock to erode.

5. Based on your model, can you identify where the highest and lowest areas of your map are located? Why or why not?

Part B: Geologic Mapping of Depositional Landscapes

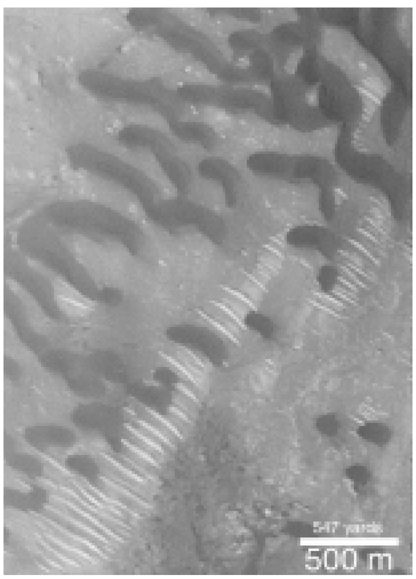


Uranius Tholus, Mars.

Background/Introduction:

Along with erosional processes, **depositional** processes also help to shape a landscape. Some depositional processes include **volcanism, mass wasting**, and wind or **aeolian action**. Volcanoes can blanket a landscape with lava flows and ash deposits. According to the **Law of Cross-cutting Relationships**, if one lava flow covers another flow, the one on top is the youngest and the flow that is **truncated** (cut off) is older. Mass wasting occurs on steep or unstable slopes when rocks can no longer support themselves and collapse. Landslides and avalanches are examples of mass wasting. Aeolian processes involve wind. Wind can carry sand and small grains of sediment from one place to another. This is called aeolian transport. Wind can also move grains along the ground by a process called **saltation**. A good example of aeolian deposition and transport is seen in sand dunes. A constant wind can migrate an entire sand dune downwind. Aeolian activity is very common on Mars. It is the driving force behind the gigantic sand and dust storms that we see on images of the planet. Mars also has landforms that look like they were carved by **fluvial processes** (running water). Although no liquid water is presently seen on the surface of Mars, it might have formed these features at some point in Mars' history.

Lava flows on Mars.



Different types of sand dunes on Mars.

Show students the shaded relief mosaic of the Tharsis region of Mars included in the trunk (USGS Map I-2458 (MC-9)). This map is a mosaic of many individual images cut and pasted together to show a larger region. This map shows volcanoes and their associated lava flows. These mosaics are used by planetary geologists as a base or starting point from which to make geologic maps. Show the students *Overhead B1*, a geologic map of Olympus Mons and its associated volcanic deposits. Talk about colors representing different rock units. Find the summit caldera complex. Show students *Overhead B2*. Ask them what they see. This is how lava flows look in spacecraft images. *Overhead B3* illustrates aeolian action. What is shown? Ask students why younger dunes appear darker than the older ones. This may be because the dunes are made of different materials.

Now, students will learn how to interpret the geology of depositional environments or regions. Students will receive materials similar to those in Part A of this lesson. Begin by laying down 2 horizontal rock units at the bottom of the box. However, this time, instead of simply cutting eroded material out, students will add newer younger layers to the top of their terrain, as well as cut away some older material. *Some of the same rules apply here as in Part A, but now there are exceptions allowed (read below).*

Students will need to refer to the map key to determine what geologic structures, such as volcanoes and impact craters, are on their map so they can build them correctly in their terrain model. Symbols for features such as lava flows and sand dunes are shown on the key.

Impact craters can leave deposits called **ejecta blankets**. Ejecta blankets are composed of rocks and other debris excavated, or blown out, during impact of the meteorite. Extraterrestrial material that came from the obliterated meteorite can also be part of an ejecta blanket (for more information on impact craters, see the Impact Crater Module of the Astrogeology Resource Packet). Ejecta blankets commonly surround a crater and are usually higher than the surrounding terrain.

In Part A, students were working strictly with sedimentary rock layers that were deposited in horizontal layers. In Part B they will be dealing with **igneous rocks** as well. Igneous rocks form either above or below the surface of a planet from cooling and solidification of molten rock, **magma** (below the surface) or **lava** (above the surface).

In this lesson it is not necessary for all of the units to be laid down in horizontal layers. It is also not necessary for the rock units to be layered sequentially from oldest to youngest. For example, if a terrain has been eroded exposing many old layers and later a volcano erupts depositing a lava flow over the older layers, the youngest rock unit (lava flow) will directly overlay a number of older rock units. Furthermore, the principle of embayment might allow a younger unit, such as a lava flow, to be located right next to an older rock unit, such as a sedimentary rock unit.

Materials:

- Clay or play dough in 10 assorted colors (see recipe at end of next page)
- Clear plastic or shoe boxes (provided)
- Depositional landscape geologic maps, color keys, and map keys (provided)
- Plastic knifes or Popsicle sticks (provided)
- Map I-2458 (MC-9) - Revised Shaded Relief Map and Controlled Color Photomosaic of the Tharsis Quadrangle of Mars (provided)

Procedure:

1. Divide students into groups of 4 or 5.
2. Each group will receive a depositional landscape geologic map, color key, and map key, 10 bags of assorted colored play dough representing different rock units, and a plastic knife or Popsicle stick to cut out and outline geologic contacts.
3. Each group will lay down 2 horizontal rock layers labeled 1 and 2 at the bottom of their box.
4. Construct a depositional terrain model similar to the group's geologic map.
5. See figures below for examples of how to set up terrain models.

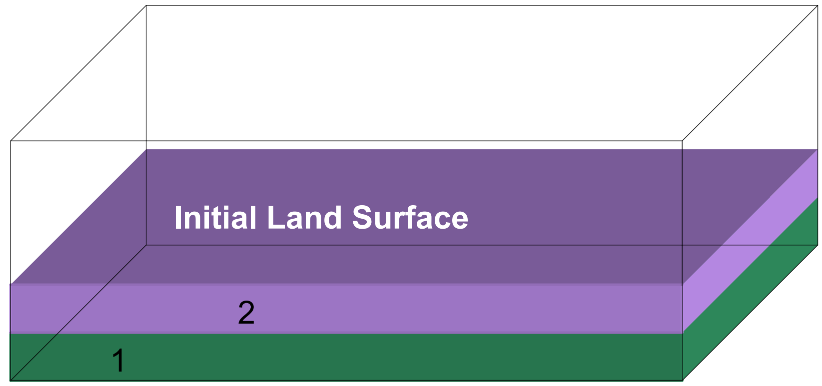


Figure 1a. Initial surface of the box; showing the first 2 layers students put in box.

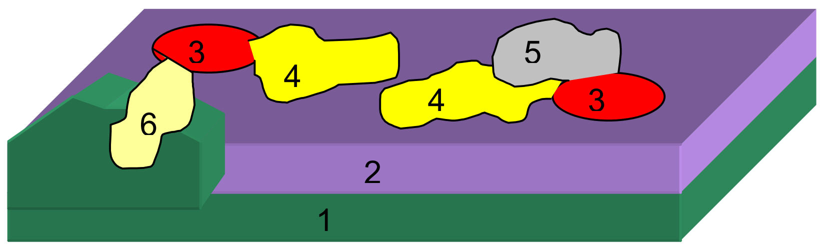


Figure 1b. Finished terrain model surface could resemble this.

In Figure 1b the rock units are numbered from oldest to youngest starting with the number 1. Notice that the gray and light yellow lava flow units are given the numbers 5 and 6. Since they are not contiguous, overlapping, or embaying into each other it is impossible to tell which one is older. Therefore, when labeling units like these, it is acceptable to label them in any order.

Assessment:
After groups have completed their models, have them answer the questions on the student sheet and then take their models to the front of the room. Collect the student question sheets and corresponding geologic maps. Set up the models and the maps on a table in random order. Have students match the correct model to each geologic map and collect their answers.

Vocabulary:
Deposition, volcanism, mass wasting, aeolian action, Law of Cross-cutting Relationships, truncated, saltation, fluvial processes, ejecta blanket, igneous rock, magma, lava

Play dough Recipe:
1 cup flour
½ cup salt
1 Tablespoon oil
2 teaspoons cream of tarter
1 cup water
Food coloring

Mix all ingredients in saucepan. Heat on low, stirring constantly until dough is evenly mixed and forms a ball. Knead slightly. Store in an airtight container or plastic baggie.

Part B: Geologic Mapping of Depositional Landscapes - Student Sheet

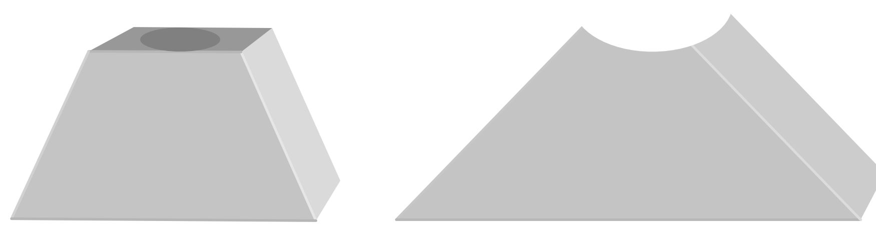
Name________________________________

In Part A, you were working strictly with sedimentary rock layers that were deposited in horizontal layers. In Part B you will be dealing with **igneous rocks** as well. Igneous rocks form either above or below the surface of a planet from cooling and solidification of molten rock, **magma** (below the surface) or **lava** (above the surface).

In this lesson it is not necessary for all of the units to be laid down in horizontal layers. It is also not necessary for the rock units to be layered sequentially from oldest to youngest. For example, if a terrain has been eroded exposing many old layers and later a volcano erupts depositing a lava flow over the older layers, the youngest rock unit (lava flow) will directly overlay a number of older rock units. Furthermore, the principle of embayment might allow a younger unit, such as a lava flow, to be located right next to an older rock unit, such as a sedimentary rock unit.

Directions:
- You will be divided into groups of 4 or 5.
- Each group will receive a depositional landscape geologic map, color key, and map key, 10 bags of assorted colored play dough representing different rock units, and a plastic knife or Popsicle stick to cut out and outline geologic contacts.
- Each group will lay down 2 horizontal rock layers labeled 1 and 2 at the bottom of their box.
- Then construct a depositional terrain model similar to your geologic map.
- Use the map key to determine what geologic structures are on your map (volcanoes, impact craters, rivers, sand dunes, etc…)
- Use play dough to make all of the volcanoes in your model in the shape of a dome or cone (see the examples below).

Examples of volcanic shapes



Questions:

1. Which of the volcanoes in your model is oldest? How can you tell?

2. What are three ways that rock units get deposited?

3. If there are sand dunes in your model, what depositional process might have created them?

4. Notice the square box on your geologic map. List the rock units in order from oldest to youngest within the box. Can you be sure of your units and their order?

5. Could there be older lava flows completely covered by younger ones?

Part C: Geologic Mapping of Deformed Landscapes

Background/Introduction:

Although many rock layers in the Earth's crust were initially deposited as flat horizontal layers, virtually every **rock outcrop** shows some evidence of **deformation**. Show *Overheads C1 and C2,* examples of deformed rocks. We often think of rocks as hard and permanent things, but they are no match against the tremendous power of tectonics. **Stress** and **strain** exerted on rocks can cause them to change shape or volume. There are three types of stress: **compression**, **tension**, and **shearing**. Compression is the pushing together of rocks. For example, when you push the edge of a rug on a hardwood floor, the rug will fold in on itself. Demonstrate this using the rug or placemat included. Over time, compressional forces can fold rock in much the same way. **Synclines** and **anticlines** (*Overhead C3*) are the result of compressional forces. Show *Overhead 3d*, a diagram showing a folded rock sequence. Tension pulls rocks apart or stretches them, much like a rubber band stretches when you pull on it. Shearing is obliquely directed compression or tension. This type of force tends to break rocks into sections that slide parallel to each other. Faulting is often the result of shearing.

Geologists look at deformed rocks to interpret the tectonic history of a region, gain insight into stress and strain directions, and help predict movement on faults and along plate tectonic boundaries. Deformation can be seen in rock that are **folded** or **faulted**, or where two or more lithospheric plates meet. Other structures that result from deformation are domes and basins.

Rocks are harder at the Earth's surface than deep within the crust and tend to break instead of bend or stretch when compressive, tensile, and shear forces are applied to them. When a rock breaks, the break is called a **fracture**. A **fault** is a fracture that clearly shows relative movement from one side to the other.

In this lesson students will focus on folded rocks and will make models of anticlines and synclines. They will then cut their model in half and make a geologic map of the section and answer related questions.

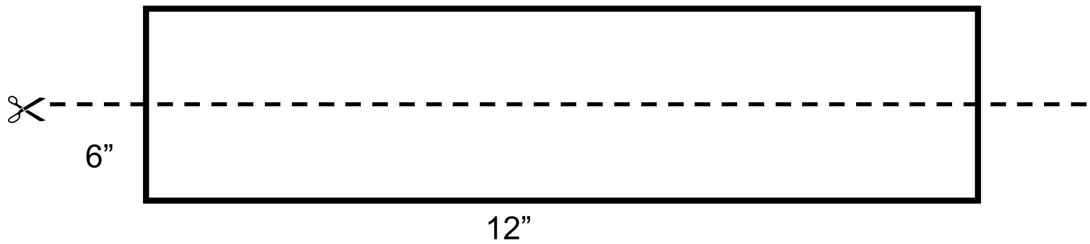
Materials:

- Small area rug or placemat (provided)
- Play dough (5 colors) (see recipe at the end of this lesson)
- Plastic knifes (provided)
- Lids to plastic boxes (provided)
- Colored pencils or crayons
- Geologic map template (provided)

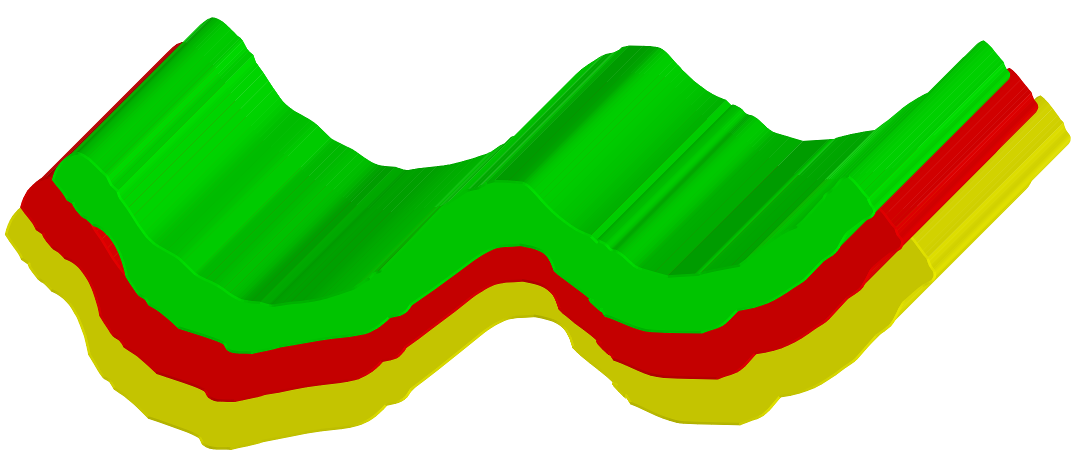
Procedure:

1. Divide students into groups of 2.
2. Give each group five bags of assorted play dough colors, a plastic knife or other cutting object, colored pencils that match the color of play dough each group receives, and a geologic map template.

3. Students will cut three equal sized rectangles out of different colored play dough. The rectangles should be 6” x 12”. (For a good estimate use the topside of a lid from the plastic boxes included in the module)
4. Have the students gently place the three layers on top of each other.
5. They will then slice the rectangle in half to create two rectangles that are 3” x 12”. See diagram below.

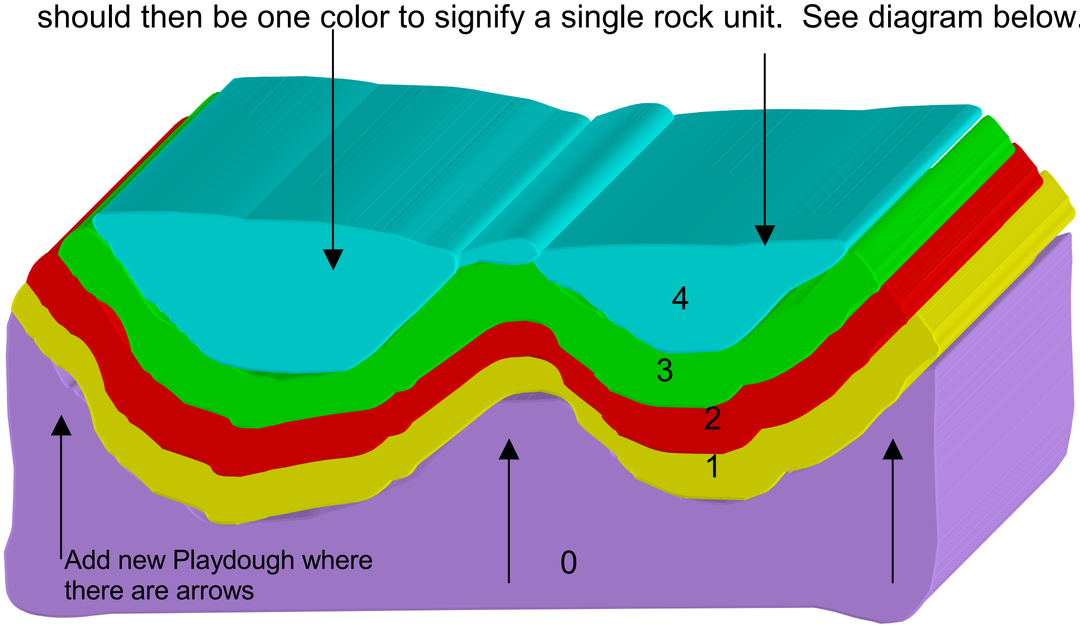


6. On their geologic map template have students create a map key. Each layer of play dough should be labeled with a number. Number 1 being the oldest layer or the one on bottom.
7. Each student will receive a 3” x 12” rectangle of play dough.
8. Gently put compressive stress on the rectangle by pushing the ends together. See diagram below.

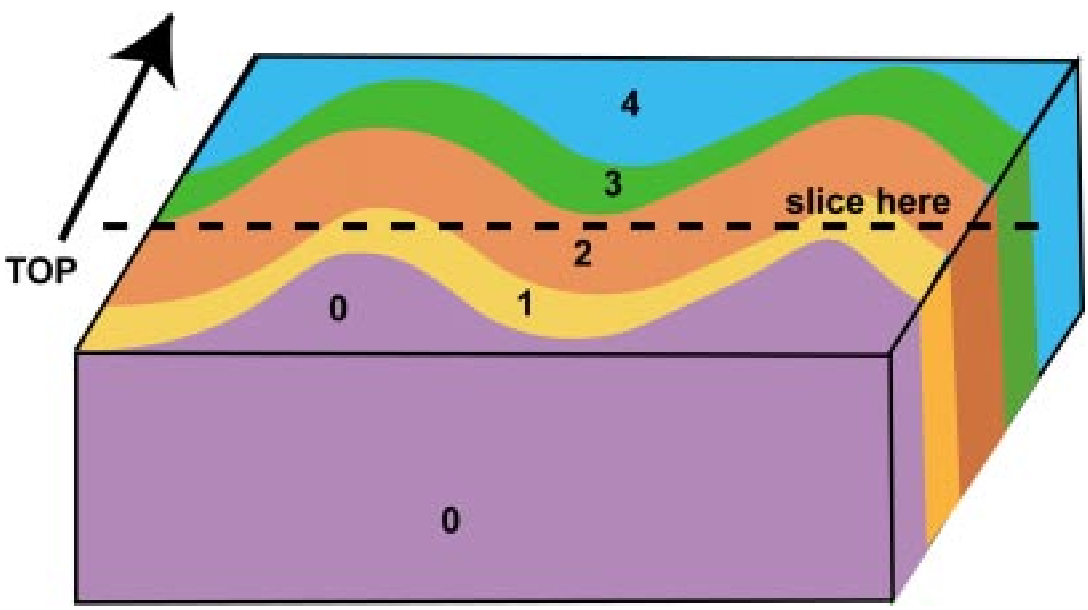


Resulting model should look similar to this.

9. Students have modeled a folded rock sequence composed of three rock units. Ask them to point out the anticlines and synclines.
10. Have students use the other two colors of play dough to make a rectangular solid out of their model. Do this by filling in the spaces in between the anticlines and synclines to make a flat surface on all sides of the model. The top of the model should then be one color to signify a single rock unit. See diagram below.



11. Next, have students lay their model on its side and cut the model in half. See diagram below.



12. Have students turn their entire model upright and remove the top half. Set this section aside for later investigation.
13. Now make a geologic map of the exposed surface along the top of the bottom half of their model using the template provided. Make sure students include a key and label all of the units with numbers. They will have to modify their original key containing only three layers to include the two new layers. The oldest layer will now be 0 (the layer below layer 1).
14. Have students separate the layers of Play dough and replace them in the correct bags. Clean work area and return all supplies to the appropriate place.

Assessment:
After completing their maps, students will answer questions on the Student Sheet and turn it in along with their geologic maps for a grade.

Closure:
To reinforce lesson concepts, go over some of the questions on the Student Sheet and ask students what they thought about the lesson. Ask if they can think of another way to learn the same concepts.

Vocabulary:
Rock outcrop, deformation, stress, strain, compression, tension, shearing, synclines, anticlines, folded, faulted, fracture

References:

- www.cnr.colostate.edu/.../htmls/ syncline-anticline.html
- www.umbc.edu/.../geog110/geog110lecture/ 14B/sld006.htm
- www.uoregon.edu/~millerm/ TF1.htmlhttp://www.uoregon.edu/~millerm/ TF1.html
- http://www.abs.sdstate.edu/plantsci/nat_res_field_trips/BlackHills/Geomorphological_oddities.gif
- Mapping the Solar System poster, USGS (provided)

Play dough Recipe:
1 cup flour
½ cup salt
1 Tablespoon oil
2 teaspoons cream of tarter
1 cup water
Food coloring

Mix all ingredients in saucepan. Heat on low, stirring constantly until dough is evenly mixed and forms a ball. Knead slightly. Store in an airtight container or plastic baggie.

Part C: Geologic Mapping of Deformed Landscapes - Geologic Map Template

Name______________________

Part I.
Color and label the key below to represent the play dough rock layers you used. Remember, the oldest unit is always given the lowest number.

KEY #1

Youngest layer

Oldest layer

Part II.
After you have added two more play dough layers, one on top and one on bottom, use the boxes provided below to make a new key, **KEY #2**. Remember, the oldest unit has changed since you made KEY #1. HINT: it is ok to use the number 0 to represent the oldest layer. Create a geologic map by drawing geologic contacts and coloring the units as shown on your surface.

GEOLOGIC MAP

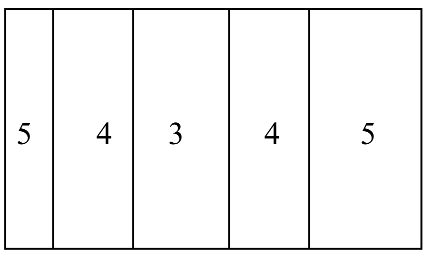
KEY #2

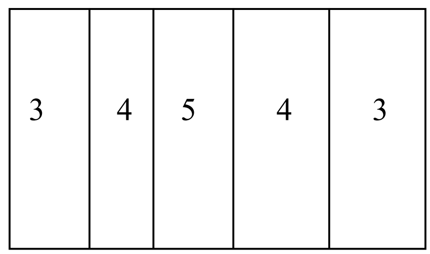
Part C: Geologic Mapping of Deformed Landscapes – Student Sheet

Name________________________________

1. How can you use your numbered rock units to distinguish between an anticline and a syncline?

2. Below are 2 diagrams in plan view (looking down from above). Label the diagrams as an exposed anticline or syncline.





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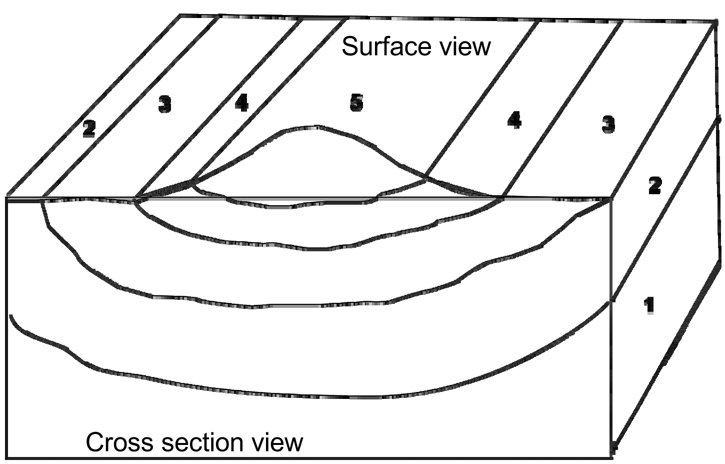
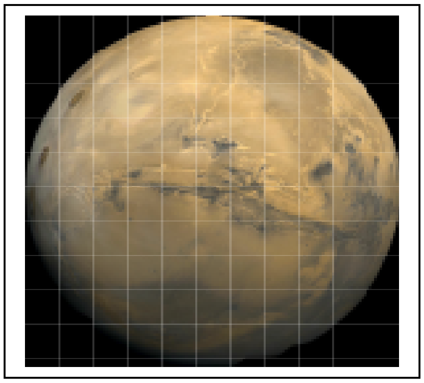
3. Below is a diagram of a tectonic structure. Is this an anticline or a syncline? Explain your answer.

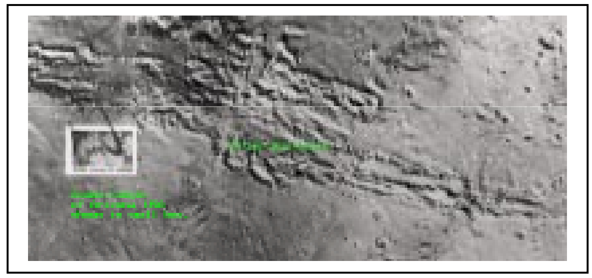


ANSWER:

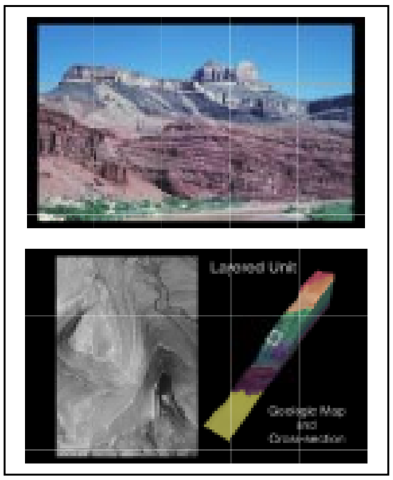
Overheads



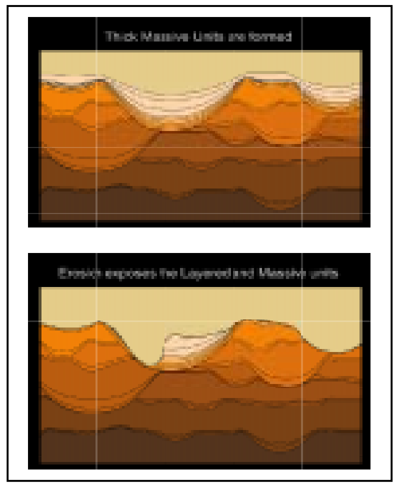
Overhead A1. Mars global view.



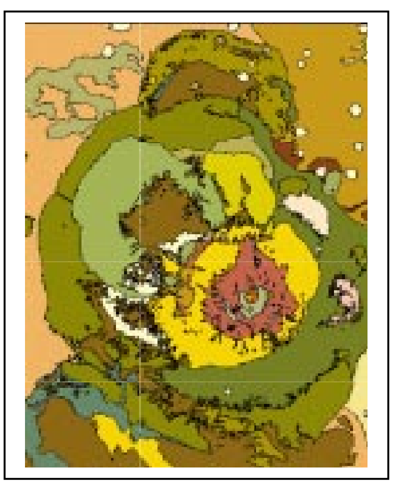
Overhead A2. Vallis Marineris vs. the Grand Canyon.



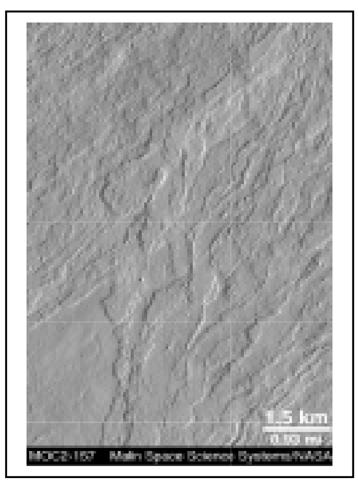
Overhead A3. Sedimentary rock layers exposed.



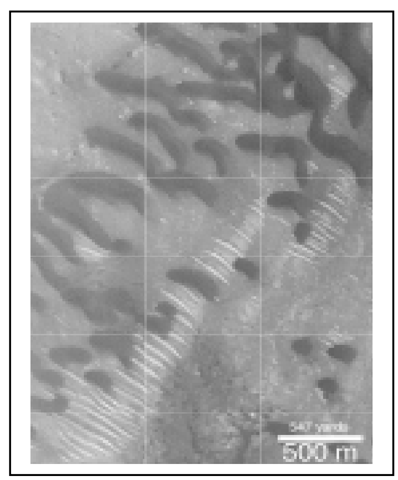
Overhead A4. Erosion on Mars.



Overhead B1. Geologic map of Olympus Mons.

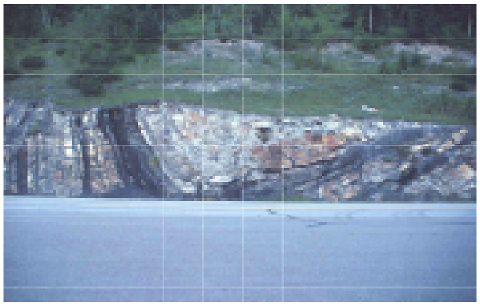


Overhead B2. Lava flows on Mars.

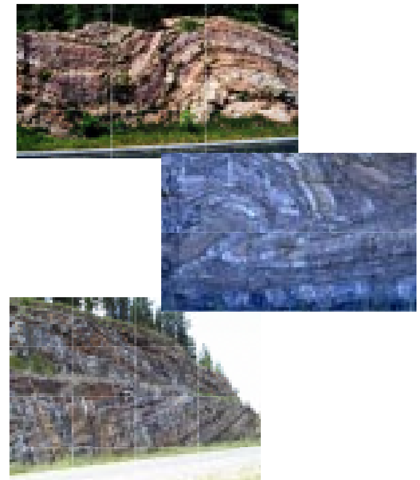


Overhead B3. Sand dunes on Mars.

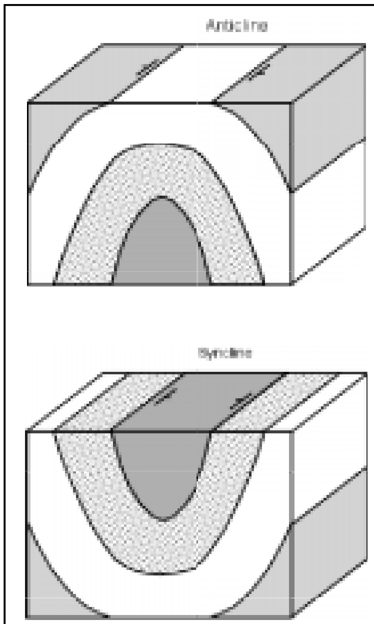
Overheads, continued



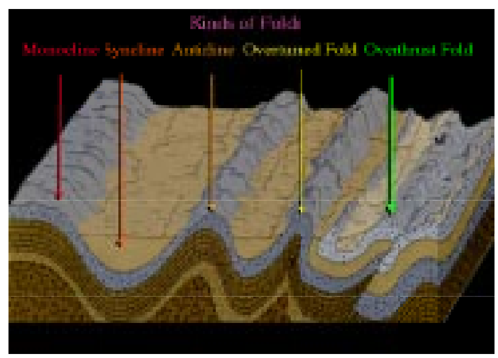
Overhead C1. Deformed rock units.



Overhead C2. More deformed rock units.



Overhead C3. Schematics of anticline and syncline.



Overhead C4. Kinds of folds.